

CLAIMS:

1. A method of preparing p-type group II-VI semiconductor material comprising:
 - obtaining a self supporting substrate surface; and
 - depositing a thin film of a group II-VI semiconductor comprising atoms of group II elements and atoms of group VI elements, wherein the group II-VI semiconductor is doped with one or more p-type dopants on the substrate surface under deposition conditions in which the group II atoms, group VI atoms, and p-type dopant atoms are combined as the thin film of group II-VI semiconductor, wherein the resulting thin film of group II-VI semiconductor is a persistent p-type semiconductor and the p-type dopant concentration in the group II-VI semiconductor is greater than about 10^{16} atoms·cm⁻³ and wherein the semiconductor resistivity is less than about 0.5 ohm·cm.
2. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the group II elements are selected from zinc, cadmium, alkaline earth metals, and mixtures thereof.
3. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the group VI elements are selected from oxygen, sulfur, selenium, tellurium, and mixtures thereof.
4. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the p-type dopant is selected from nitrogen, phosphorus, arsenic, antimony, bismuth, copper, and chalcogenides of the foregoing, and mixtures thereof.
5. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the p-type dopant is phosphorus.
6. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the p-type dopant is arsenic.
7. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the p-type dopant is antimony.
8. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the p-type dopant is bismuth.
9. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the p-type dopant is copper.

10. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein self supporting substrate surface is amorphous.

11. A method of preparing p-type group II-VI semiconductor material according to claim 10, wherein the substrate surface is fused silica (SiO₂).

12. A method of preparing p-type group II-VI semiconductor material according to claim 10, wherein the substrate is an amorphous SiO₂ coating on silicon wafer.

13. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the self supporting substrate surface is polycrystalline alumina.

14. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the thin film of a group II-VI semiconductor is deposited by a chemical deposition process selected from RF sputtering, CVD (chemical vapor deposition), MOCVD (metal organic chemical vapor deposition), spin coating, electrophoresis, and hydrothermal growth processes.

15. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the group II-VI semiconductor material is zinc oxide.

16. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the group II-VI semiconductor material is zinc sulfide.

17. A method of preparing p-type group II-VI semiconductor material according to claim 1, wherein the group II-VI semiconductor material is deposited as a single crystal.

18. A method of preparing p-type zinc oxide semiconductor material comprising:
 - obtaining a self supporting substrate surface; and
 - depositing a thin film of zinc oxide doped with one or more p-type dopants on the substrate surface under deposition conditions in which zinc, oxygen, and p-type dopant atoms are combined as the thin film of zinc oxide, wherein the resulting thin film of zinc oxide is a persistent p-type semiconductor and the p-type dopant concentration in the zinc oxide is greater than about 10^{16} atoms·cm⁻³ and wherein semiconductor resistivity is less than about 0.5 ohm·cm.
19. A method of preparing p-type zinc oxide semiconductor material according to claim 18, wherein the p-type dopant is selected from nitrogen, phosphorus, arsenic, antimony, bismuth, copper, and chalcogenides of the foregoing, and mixtures thereof.
20. A method of preparing p-type zinc oxide semiconductor material according to claim 18, wherein the p-type dopant is phosphorus.
21. A method of preparing p-type zinc oxide semiconductor material according to claim 18, wherein the p-type dopant is arsenic.
22. A method of preparing p-type zinc oxide semiconductor material according to claim 18, wherein the p-type dopant is antimony.
23. A method of preparing p-type zinc oxide semiconductor material according to claim 18, wherein the p-type dopant is bismuth.
24. A method of preparing p-type zinc oxide semiconductor material according to claim 18, wherein the p-type dopant is copper.

25. A method of preparing p-type zinc oxide semiconductor material comprising:
obtaining a self supporting substrate surface; and
depositing a thin film of single crystal zinc oxide doped with arsenic on the substrate surface under deposition conditions in which the zinc, arsenic, and oxygen atoms are combined as the thin film of zinc oxide, wherein the resulting thin film of zinc oxide is a persistent p-type semiconductor and the arsenic concentration in the zinc oxide is greater than about 10^{16} atoms·cm⁻³, wherein semiconductor resistivity is less than about 0.5 ohm·cm, and wherein the carrier mobility is greater than about 0.1 cm²/V·s.

26. A method of preparing p-type zinc oxide according to claim 25, wherein the zinc, arsenic, and oxygen atoms are deposited by RF sputtering such that the under deposition conditions in which the zinc, arsenic, and oxygen atoms are in a gaseous phase prior to combining as the thin film.

27. A method of preparing p-type zinc oxide according to claim 25, wherein the zinc, arsenic, and oxygen atoms are deposited by a chemical deposition process selected from CVD (chemical vapor deposition), MOCVD (metal organic chemical vapor deposition), spin coating, electrophoresis, and hydrothermal growth processes.

28. A method of preparing p-type zinc oxide according to claim 25, wherein the step of depositing the thin film of zinc oxide doped with arsenic comprises:

depositing a thin film on the substrate surface comprising zinc and arsenic; and
sputtering the thin film of zinc oxide doped with arsenic onto the substrate surface at a temperature at which a portion of the arsenic is in the gas phase.

29. A method of preparing p-type zinc oxide according to claim 28, wherein the thin film comprising zinc and arsenic is Zn₃As₂, ZnAs₂, ZnAs, or a mixture thereof.

30. A method of preparing p-type zinc oxide according to claim 28, wherein the thin film comprising zinc and arsenic was deposited on the substrate by thermal evaporation.

31. A method of preparing p-type zinc oxide according to claim 28, wherein the thin film comprising zinc and arsenic was deposited on the substrate by a combination of sputtering and thermal evaporation.

32. A method of preparing p-type zinc oxide according to claim 25, wherein the step of depositing the thin film of zinc oxide doped with arsenic comprises:

sputtering the thin film using a sputtering system having a target comprising from about 0.99 to about 0.95 mole % zinc oxide and about 0.01 to about 0.05 mole % arsenic and having a sputtering atmosphere comprising an inert sputtering gas.

33. A method of preparing p-type zinc oxide according to claim 32, wherein - wherein the sputtering system operates at a power in the range from about 20 to about 120 watts.

34. A method of preparing p-type zinc oxide according to claim 32, wherein the inert sputtering gas is present in the sputtering atmosphere at a pressure in the range from about 4 to 20 mtorr.

35. A method of preparing p-type zinc oxide according to claim 32, wherein the sputtering atmosphere further comprises oxygen gas at a pressure in the range from about 1 to 4 mtorr.

36. A method of preparing p-type zinc oxide according to claim 32, wherein the inert sputtering gas is selected from argon, krypton, xenon, neon, and helium.

37. A method of preparing p-type zinc oxide according to claim 32, wherein the sputtering atmosphere further comprises oxygen gas and wherein the method of preparing p-type zinc oxide semiconductor material further comprises the step of annealing the thin film of zinc oxide at a temperature in the range from about 300 to about 450 °C for a time period in the range from about 1 to about 15 minutes.

38. A method of preparing p-type zinc oxide according to claim 25, wherein the step of depositing the thin film of zinc oxide doped with arsenic comprises:

sputtering the thin film using a sputtering system having a target comprising from about 0.99 to about 0.95 mole % zinc and about 0.01 to about 0.05 mole % arsenic oxide (As_2O_3) and having a sputtering atmosphere comprising an inert sputtering gas.

39. A method of preparing p-type zinc oxide according to claim 38, wherein the sputtering system operates at a power in the range from about 15 to about 40 watts.

40. A method of preparing p-type zinc oxide according to claim 38, wherein the inert sputtering gas is present in the sputtering atmosphere at a pressure in the range from about 4 to 20 mtorr.

41. A method of preparing p-type zinc oxide according to claim 38, wherein the sputtering atmosphere further comprises oxygen gas at a pressure in the range from about 1 to 4 mtorr.

42. A method of preparing p-type zinc oxide according to claim 38, wherein the inert sputtering gas is selected from argon, krypton, xenon, neon, and helium.

43. A method of preparing p-type zinc oxide according to claim 38, wherein the sputtering atmosphere further comprises oxygen gas and wherein the method of preparing p-type zinc oxide semiconductor material further comprises the step of annealing the thin film of zinc oxide at a temperature in the range from about 300 to about 450°C for a time period in the range from about 1 to about 15 minutes.

44. A method of preparing p-type zinc oxide according to claim 25, wherein the step of depositing the thin film of zinc oxide doped with arsenic comprises:

depositing the thin film of zinc oxide doped with arsenic on the substrate by thermal evaporation, wherein the thermal evaporation occurs in an oxygen-rich atmosphere to partially oxidize the zinc and form the p-type zinc oxide semiconductor material.

45. A method of preparing p-type zinc oxide according to claim 44, further comprising the step of annealing the p-type zinc oxide semiconductor material.

46. A method of preparing p-type zinc oxide according to claim 44, wherein the oxygen content during the thermal evaporation was at least 10 mtorr oxygen.

47. A method of preparing p-type zinc oxide according to claim 44, wherein the thermal evaporation occurs at a temperature of about 450°C ± 20 °C.

48. A method of preparing p-type zinc oxide according to claim 44, further comprising the step of annealing the thin film of zinc oxide at a temperature in the range from about 300 to about 430°C for a time period in the range from about 1 to about 15 minutes.

49. A method of preparing p-type zinc oxide semiconductor material comprising:
obtaining a self supporting substrate surface; and
depositing a thin film of single crystal zinc oxide doped with antimony on the
substrate, wherein the resulting thin film of zinc oxide is a persistent p-type
semiconductor and the antimony concentration in the zinc oxide is greater than about
 10^{16} atoms \cdot cm $^{-3}$, wherein semiconductor resistivity is less than about 0.5 ohm \cdot cm, and
wherein the carrier mobility is greater than about 0.1 cm 2 /V \cdot s.

50. A method of preparing p-type zinc oxide according to claim 49, wherein the step
of depositing the thin film of zinc oxide doped with antimony comprises:

sputtering the thin film using a sputtering system having a target comprising zinc
and antimony and having a sputtering atmosphere comprising an inert sputtering gas.

51. A method of preparing p-type zinc oxide according to claim 49, wherein the
sputtering system operates at a power in the range from about 15 to about 40 watts.

52. A method of preparing p-type zinc oxide according to claim 49, wherein the
inert sputtering gas is present in the sputtering atmosphere at a pressure in the range from about
4 to 20 mtorr.

53. A method of preparing p-type zinc oxide according to claim 49, wherein the
sputtering atmosphere further comprises oxygen gas at a pressure in the range from about 1 to 4
mtorr.

54. A method of preparing p-type zinc oxide according to claim 49, wherein the
inert sputtering gas is selected from argon, krypton, xenon, neon, and helium.

55. A method of preparing p-type zinc oxide according to claim 49, wherein the
sputtering atmosphere further comprises oxygen gas and wherein the method of preparing p-
type zinc oxide semiconductor material further comprises the step of annealing the thin film of
zinc oxide at a temperature in the range from about 300 to about 430 °C for a time period in the
range from about 1 to about 15 minutes.

56. A method of preparing p-type zinc oxide according to claim 49, wherein the
target comprises from about 0.99 to about 0.95 mole % zinc and about 0.01 to about 0.05 mole
% antimony oxide (Sb₂O₃).

57. A method of preparing p-type zinc oxide according to claim 49, wherein the target comprises from about 0.99 to about 0.95 mole % zinc oxide and about 0.01 to about 0.05 mole % antimony.

58. A method of preparing p-type zinc oxide according to claim 49, wherein the target comprises from about 0.99 to about 0.95 mole % zinc and about 0.01 to about 0.05 mole % antimony, and wherein the sputtering atmosphere further comprises oxygen.

59. A method of preparing p-type zinc oxide according to claim 49, wherein the target comprises from about 0.99 to about 0.95 mole % zinc oxide and about 0.01 to about 0.05 mole % antimony oxide (Sb_2O_3).